

Fuzzy logic offers new ways to solve tough control problems

By blurring the line between true and false, manufacturers say they're improving complex-system design

Newton, MA—Maytag, General Motors, John Deere, Eaton Corp., and NASA. What do these U.S. enterprises have in common? They're all using fuzzy logic and aren't afraid to say so. Maytag's IntelliSense™ dishwasher uses fuzzy logic to decide exactly how long to wash dishes, thus saving energy, water, and time. In GM Saturns with automatic transmissions, a fuzzy-logic controller mimics an expert's down-shifting skills. Engineers at Deere's Industrial Equipment Division are using fuzzy logic to make construction equipment easier to control, Eaton is working on fuzzy-logic sensors, and NASA is using the technology to control the next generation of a power wrench for use in space.

Lots of other companies are using fuzzy logic, some with great success. In fact, some analysts say that a leading color-printer company is using fuzzy logic, as well as almost every car company.

Fuzzy what? Fuzzy logic is based on fuzzy set theory, a mathematical discipline invented in the U.S. This theory allows for shades of gray between absolute truth and falseness, unlike bitlevel logic, which holds that a statement must be 100% true or false. In

fuzzy logic, a statement such as, "Julie is driving fast," can be 75% true and 25% false if Julie is cruising the highway at, say, 70 mph.

Fuzzy logic lets engineers control real-world systems by using language-based rules rather than rigorous mathematical modeling. It has proven especially effective for situations having complex equations, lots of exceptions to the

development engineer with John Deere, "instead of coming up with one equation for everything, designers write rules that tell the controller what they want it to do for every combination of error, derivative of error, and whatever other conditions they want to look at." Construction equipment encounters such nonlinear factors as soil condition and traction.

Deere looks to fuzzy-logic

well as sensor inputs from the machine to help the machine do a better job—even with a mediocre operator.

Reported fuzzy benefits include: accelerated R&D, reduced time to market, simpler solving of complex control problems, and the ability to get more horsepower out of a given processor. "Fuzzy logic has the potential to have the same impact on technology over the next two decades that the microprocessor had over the last two," forecasts fuzzy-logic consultant David Brubaker.

There are drawbacks. There is no formal method for designing fuzzy systems. In addition, the resulting system is not analytic, and you generally cannot prove a system's stability on paper. "But remember," notes Brubaker, "fuzzy logic was developed for complex systems for which designers could not create mathematical models or whose models were gross simplifications."

The field incorporates some comical-sounding terminology. Values are "fuzzy" or "crisp." Converting crisp values to fuzzy values is "fuzzifying." And computing a crisp output from fuzzy membership functions is deemed "defuzzification."

"Fuzzy logic is just a horrible name," says Rod Hemmerlein,

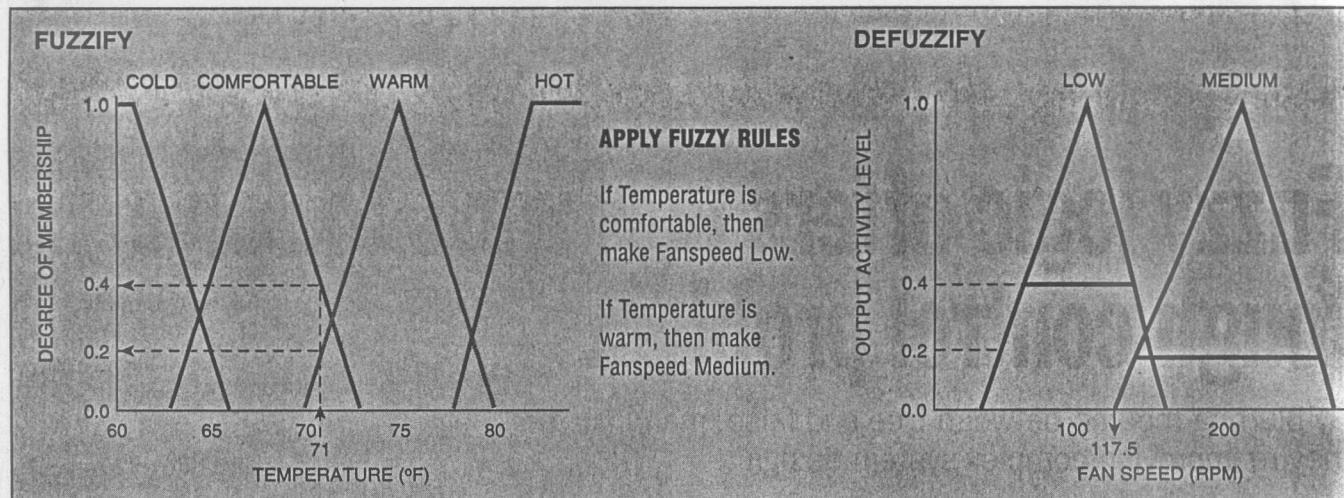


NASA is using fuzzy logic to control the next generation of astronaut power tools, such as this variable-speed, variable-torque wrench (A).

equations, nonlinearities to accommodate, system inputs that provide vague or ambiguous information, or no equations at all.

A PID control system is an example of a traditional, linear approach. "With fuzzy logic," says Boyd Nichols, senior

technology to make machines easier to manage. One example is a bulldozer making a level cut straight ahead. This is a job that requires years—even decades—of experience, says Nichols. A fuzzy control system makes use of knowledge of the experienced operator as



Fuzzification converts crisp (numerical) input values, in this case temperatures, into degrees of membership in the fuzzy input sets: cold, comfortable, warm, and hot. The value 71°F has degree of membership 0.4 in fuzzy set Comfortable and 0.2 in the fuzzy set Warm.

fuzzy technologies product manager at Inform Software, Oak Brook, IL, which develops fuzzy-logic tools and conducts training. "It should have been called multivariate math or something like that. When I tell my friends what I do for a living, they kind of laugh at me."

Adds Nichols: "People have a bad response to the word 'fuzzy'—it doesn't seem worthy of an industrial machine and connotes imprecision."

Lack of understanding also keeps some designers from trying fuzzy logic. Will Schrieber, senior program

manager at Intel's Embedded Microcontroller Division, resells Inform software products with embedded control tools for Intel chips. He says he's developed fuzzy-logic solutions for key accounts and handed it to them. "They evaluated it but because they didn't truly understand the technology, they didn't want to deal with it. They'd rather use a high-powered mathematical program and a DSP chip as opposed to going with fuzzy logic, which might give them a 10% performance improvement using a less expensive

chip. The American mode is brute force."

Competitive edge. Inform's Hemmerlein says he does have some U.S. customers doing great things with fuzzy logic, but they won't let him publicize their names. "One company implemented a control algorithm in fuzzy logic and was surprised at how compact and efficient the code was compared with the previous C code. They went from using a DSP to using a far-cheaper 8-bit microcontroller. They say they're leaps and bounds ahead of the competition right now, and they

don't want to tell people."

Even though fuzzy logic hasn't caught on as quickly in the U.S. as experts expected they're still hopeful. But even advocates don't regard fuzzy logic as the answer to all control problems. "It's not panacea," says Brubaker. "You success will depend on how good an engineer you are and how familiar you are with the problem."

—Julie Anne Schofield
Associate Editor

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Fuzzy-logic resources

Two new books not only describe how fuzzy logic works, but also give application examples. The first, *Fuzzy Logic & Neurofuzzy Applications Explained*, by Constantin von Altrock (Prentice-Hall, Englewood Cliffs, NJ, ISBN 0-13-368465-2, \$39.95), delves into more than 30 case studies. The second, *Industrial Applications of Fuzzy Logic and Intelligent Systems*, edited by John Yen, Reza Langari, and Lofti A. Zadeh (IEEE Press, Piscataway, NJ, ISBN 0-7803-1048-9, \$64.95), is an anthology of fuzzy-logic success stories from researchers in Japan, Europe, and the U.S.

For \$199, Motorola offers FLEDKT01—an educa-

tion kit that includes a demo version of FIDE software from Aptronix, San Jose, CA, that generates C and assembler code for several 8- and 16-bit Motorola microcontrollers.

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Also for \$199, National Semiconductor, Santa Clara, CA, will sell you the NeuFuz4 Learning Kit.

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Inform Software Corp. has teamed up with Intel, Microchip Technology, and Texas Instruments, Siemens, and SGS-Thomson Microelectronics to provide starter tools for microprocessors, microcontrollers, and digital signal processors (DSPs) from each company. Prices start at \$200.

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